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Seismic Hazard for Selected Sites in Greece: A Bayesian Estimate of Seismic Peak Ground Acceleration

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Abstract. A procedure for estimating maximum values of seismic peak ground acceleration at the examined site and quantiles of its probabilistic distribution in a future time interval of a given length is considered. The input information for the method are seismic catalog and regression relation between peak seismic acceleration at a given point and magnitude and distance from the site to epicenter (seismic attenuation law). The method is based on Bayesian approach, which simply accounts for influence of uncertainties of seismic acceleration values. The main assumptions for the method are Poissonian character of seismic events flow and distribution law of Gutenberg-Richter's type. The method is applied to seismic hazard estimation in six selected sites in Greece.

Key words: Bayesian approach, seismic hazard assessment, peak ground accelerations.

1. Introduction

The problem of seismic hazard assessment has a lot of tools for its solution. Here we emphasize purely statistical procedures (Cornell, 1968; Benjamin and Cornell, 1970) and do not touch methods which involve direct solution of wave propagation. The advantages of statistic approach consist in its generality. We do not need to identify a lot of values of different parameters, which we must know if we try to solve differential equations and the most of which could not be defined with sufficient accuracy in principle. Among statistical methods, the Bayesian approach has a special interest which comes from its ability to take into consideration uncertainty of parameters in fitted probabilistic laws and *a priori* information. These properties of Bayesian approach make it rather popular in seismic hazard investigations (Morgat and Shah, 1979; Campell, 1982, 1983; Lamarre *et al.*, 1992). Here we present results of processing seismic catalog of Greece by Bayesian procedure, which was elaborated in previous works (Pisarenko *et al.*, 1996; Pisarenko and Lyubushin, 1997, 1999) with the purpose of estimating maximum seismic peak ground acceleration. The advantages of the method consist in its simplicity: it does not need such intermediate steps of investigation as earthquake scenarios, estimates of bimodal recurrence model of magnitude distribution, bootstrap procedures (Morgat and Shah, 1979; Lamarre *et al.*, 1992). The method is straightforward and needs only seismic catalog and attenuation law. At the same time it allows consideration of uncertainty of seismological information and thus possesses the main advantage of Bayesian approach.

2. Method

We shall present the main points of the method, following Pisarenko *et al.* (1996), and Pisarenko and Lyubushin (1997, 1999). Let R be some value, which was measured or estimated as a sequence on a 'past' time interval $(-\tau, 0)$:

$$\vec{R}^{(n)} = (R_1, \ldots, R_n),\ R_i \geq R_0,\ R_\tau = \max_{1 \leq i \leq n} (R_1, \ldots, R_n). \tag{1}$$

The values of Equation (1) could have an arbitrary physical nature. Below we shall consider Equation (1) as values of peak ground accelerations, estimated at a given site of some region. R_0 is a minimum cutoff value, i.e., such value which is defined by possibilities of registration systems or was chosen as minimum value up from which values sequence (1) is statistically representative.

First assumption for applying the method is that values (1) obey the Gutenberg–Richter law of distribution:

$$\mathrm{Prob}\{R < x\} = F(x|R_0, \rho, \beta) = \frac{\mathrm{e}^{-\beta \cdot R_0} - \mathrm{e}^{-\beta \cdot x}}{\mathrm{e}^{-\beta \cdot R_0} - \mathrm{e}^{-\beta \cdot \rho}},\ R_0 \leq x \leq \rho. \tag{2}$$

Here ρ is the unknown parameter, which has a sense of maximum possible value of R. Unknown parameter β usually is called the 'slope' of Gutenberg–Richter law at small values of x when the dependence (2) is plotted in doubly logarithmic axes.

The second assumption is that the sequence (1) is a Poissonian process with some intensity value λ, which is unknown parameter also.

Thus the full vector of unknown parameter is the following:

$$\theta = (\rho, \beta, \lambda). \tag{3}$$

Let ϵ be an error, with which we know values (1), i.e., for us really in (1) are accessible not *true*, but *apparent* values of R, which are defined by formula:

$$\bar{R} = R + \epsilon. \tag{4}$$

Let $n(x \mid \delta)$ be a density of probabilistic distribution of the error ϵ, where δ is a given scale parameter of the density. We shall use below a uniform distribution density:

$$n(x \mid \delta) = \frac{1}{2\delta}, \quad |x| \leq \delta$$
$$n(x \mid \delta) = 0, \qquad |x| > \delta. \tag{5}$$

Let $\bar{f}(R \mid \theta, \delta)$ be the probability density for apparent values, $\bar{F}(R \mid \theta, \delta)$ – its function of distribution, $\bar{\lambda}(\theta, \delta)$ – the intensity of apparent values. Then:

$$\bar{f}(x \mid \theta, \delta) = \frac{1}{(c_f A_1 - A_2)} \cdot \hat{f}, \tag{6}$$

where

$$\hat{f} = c_f \beta A(x), \text{ for } R_0 \leq x < \rho - \delta;$$

$$\hat{f} = \frac{A(x-\delta) - A_2}{2\delta}, \text{ for } \rho - \delta \leq x \leq \rho + \delta;$$

$$A(x) = \exp(-\beta x), A_1 = A(R_0), A_2 = A(\rho),$$

$$c_f = c_f(\theta, \delta) = \frac{\exp(\beta\delta) - \exp(-\beta\delta)}{2\delta}$$

and

$$\bar{F}(x \mid \theta, \delta) = \frac{1}{(c_f A_1 - A_2)} \cdot \hat{F}, \tag{7}$$

where $\hat{F} = c_f(A_1 - A(x))$, for $R_0 \leq x < \rho - \delta$

$$\hat{F} = c_f(A_1 - A(\rho - \delta)) - A_2 \cdot \frac{(x - \rho + \delta)}{2\delta} - \frac{[A(x-\delta) - A(\rho - 2\delta)]}{2\beta\delta},$$

for $\rho - \delta \leq x \leq \rho + \delta$

$$\bar{\lambda}(\theta, \delta) = \lambda \cdot c_f(\theta, \delta). \tag{8}$$

The derivation of the formulas (6), (7), (8) for the case (5) could be found in Kijko and Sellevoll (1992).

Let Π be *a priori* uncertainty domain of values of parameters θ:

$$\Pi = \{\lambda_{\min} \leq \lambda \leq \lambda_{\max}, \beta_{\min} \leq \beta \leq \beta_{\max}, \rho_{\min} \leq \rho \leq \rho_{\max}\}. \tag{9}$$

We shall consider *a priori* density of the vector θ to be uniform in the domain Π.

Let $[0, T]$ be a future interval of time for which we want to estimate function of distribution of maximum value ρ and its quantiles.

As the flow of events (1) is stationary and Poissonian then it is follows that intensity of event with $R < x$ equals $\lambda \cdot F(x \mid \theta)$ and intensity of events with $R \geq x$ equals $\lambda \cdot (1 - F(x \mid \theta))$. From Poissonian character of the events flow (1) it follows that the probability that it will be no events with $R \geq x$ on time interval $[0, T]$ or that all events on $[0, T]$ will have $R < x$ equals:

$$\exp(-\lambda \cdot (1 - F(x \mid \theta)) \cdot T). \tag{10}$$

Let's denote by R_T maximal value of R on the time interval $[0, T]$. Then $\mathrm{Prob}\{R_T < x\} = \exp(-\lambda \cdot (1 - F(x \mid \theta)) \cdot T)$. But into this probability a case when there is no events on $[0, T]$ is included also. Let's denote by v_T the number of events with $R \geq R_0$ on the interval $[0, T]$. Then

$$\mathrm{Prob}\{v_T = 0\} = \mathrm{e}^{-\lambda \cdot T}; \mathrm{Prob}\{v_T \geq 1\} = (1 - \mathrm{e}^{-\lambda \cdot T}). \tag{11}$$

That is why

$$\begin{aligned} \Phi_T(x \mid \theta) &= \mathrm{Prob}\{R_T < x \mid v_T \geq 1\} \\ &= \frac{\exp(-\lambda T(1 - F(x \mid \theta)) - \exp(-\lambda T)}{1 - \exp(-\lambda T)} \\ &= \frac{\exp(\lambda T F(x \mid \theta)) - 1}{\exp(\lambda T) - 1}. \end{aligned} \tag{12}$$

Formula (12) defines an expression for *a priori* function of distribution for *true* maximum values of R on the future time interval $[0, T]$. Let us introduce also the following functions:

$$\phi_T(x \mid \theta) = \frac{\mathrm{d}}{\mathrm{d}x}\Phi_T(x \mid \theta) \tag{13}$$

a priori probability density function for *true* maximum values of R on time interval $[0, T]$;

$$Y_T(\alpha \mid \theta) - \text{the root of equation:} \Phi_T(x \mid \theta) = \alpha, 0 \leq \alpha \leq 1 \tag{14}$$

a priori quantile for probability α for *true* maximum values of R on time interval $[0, T]$; quantile of the random value ξ of the level or probability α means a minimum root of the equation: $\mathrm{Prob}\{\xi < x\} = \alpha$ (see Kendall *et al.* (1987)).

If we substitute in formula (8) $F(x \mid \theta) \to \bar{F}(x \mid \theta, \delta)$ then we will obtain a function:

$\bar{\Phi}_T(x \mid \theta, \delta)$ – *a priori* function of distribution for *apparent* maximum values of R on future time interval [0, T].

Substituting $\bar{\Phi}_T(x \mid \theta, \delta)$ into formulae (11) and (12), we will obtain:

$\bar{\phi}_T(x \mid \theta, \delta)$ – *a priori* density for *apparent* maximum values of R on future time interval [0, T] and:

$\bar{Y}_T(\alpha \mid \theta, \delta)$ – *a priori* quantile for probability α for *apparent* maximum values of R on future time interval [0, T].

According to the definition of conditional probability, *a posteriori* density of distribution of vector of parameters $\boldsymbol{\theta}$ is equal to:

$$f(\theta \mid \vec{R}^{(n)}, \delta) = \frac{f(\theta, \vec{R}^{(n)}|\delta)}{f(\vec{R}^{(n)} \mid \delta)} \tag{15}$$

but $f(\theta, \vec{R}^{(n)} \mid \delta) = f(\vec{R}^{(n)} \mid \theta, \delta) \cdot f^a(\theta)$, where $f^a(\theta)$ is *a priori* density of distribution of vector θ in the domain Π. As $f^a(\theta)$ = constant according to our assumption and taking into consideration that:

$$f(\vec{R}|^{(n)} \mid \delta) = \int_{\Pi} f(\vec{R}^{(n)} \mid \theta, \delta)\, \mathrm{d}\theta \tag{16}$$

then we will obtain after using a Bayes formula (Rao, 1965) and normalizing the density that:

$$f(\theta \mid \vec{R}^{(n)}, \delta) = \frac{f(\vec{R}^{(n)} \mid \theta, \delta)}{\int_{\Pi} f(\vec{R}^{(n)} \mid \vartheta, \delta)\mathrm{d}\vartheta}. \tag{17}$$

In order to use (17) we must have an expression for the function $f(\vec{R}^{(n)} \mid \theta, \delta)$. Having the assumption of Poissonian character of the sequence (1) and of independence of its members, we can obtain:

$$f(\vec{R}^{(n)} \mid \theta, \delta) = \bar{f}(R_1 \mid \theta, \delta) \cdots \bar{f}(R_n \mid \theta, \delta) \cdot \frac{\exp(-\bar{\lambda}(\theta, \delta) \cdot \tau) \cdot (\bar{\lambda}(\theta, \delta) \cdot \tau)^n}{n!}. \tag{18}$$

Now we are completely ready to compute a Bayesian estimate of vector θ:

$$\hat{\theta}(\vec{R}^{(n)} \mid \delta) = \int_{\Pi} \vartheta \cdot f(\vartheta \mid \vec{R}^{(n)}, \delta)\mathrm{d}\vartheta. \tag{19}$$

Among one of its component vector (19) contains an estimate of maximum value ρ. Using analogous to (19) formula, we can obtain Bayesian estimates of any of the functions (12), (13), (14). The most interesting for us are estimates of quantiles of functions of distribution of true and apparent R-values on a given future time interval $[0, T]$, for instance for α-quantiles of apparent values:

$$\hat{\bar{Y}}_T(\alpha \mid \vec{R}^{(n)}, \delta) = \int_{\Pi} \bar{Y}_T(\alpha \mid \vartheta, \delta) \cdot f(\vartheta \mid \vec{R}^{(n)}, \delta)\, \mathrm{d}\vartheta, \tag{20}$$

$\hat{Y}_T(\delta \mid \vec{R}^{(n)}, \delta)$ for α-quantiles of true values is written analogously to (20). Using averaging over the density (17), (18) we can estimate also variances of Bayesian estimates (19), (20). For example:

$$\begin{aligned} \mathrm{var}\{\hat{\bar{Y}}_T(\alpha \mid \vec{R}^{(n)}, \delta)\} \;=\; & \int_{\Pi} (\bar{Y}_T(\alpha \mid \vartheta, \delta) \\ & -\hat{\bar{Y}}(\alpha \mid \vec{R}^{(n)}, \delta))^2 \cdot f(\vartheta \mid \vec{R}^{(n)}, \delta)\, \mathrm{d}\vartheta. \end{aligned} \tag{21}$$

In order to finish description of the method, we must define the domain of *a priori* uncertainty Π (9).

First of all we set $\rho_{\min} = R_\tau - \delta$. As for value of $\rho_{\max}$, it is introduced by the user of the method and depends of the specifics of the data series (1). Boundary values for the slope β are defined by formulae:

$$\beta_{\min} = \beta_0 \cdot (1-\gamma),\, \beta_{\max} = \beta_0 \cdot (1+\gamma),\, 0 < \gamma \le 1, \tag{22}$$

where β_0 is the 'central' value, obtained as a maximum likelihood estimate of the slope for Gutenberg–Richter law:

$$\sum_{i=1}^{n} \ln \left\{ \frac{\beta \cdot \mathrm{e}^{-\beta \cdot R_1}}{\mathrm{e}^{-\beta \cdot R_0} - \mathrm{e}^{-\beta \cdot R_\tau}} \right\} \to \max_{\beta, \beta \in (0, \beta_s)}, \tag{23}$$

where β_s is a rather big value, for example 10, γ is a parameter of the method, usually we take $\gamma = 0.5$.

For setting boundary values for intensity in (9) we use the following reasons. As a consequence of normal approximation for Poissonian process for rather big n (Cox and Lewis, 1966) variance of the value $\lambda\tau$ has approximate value $\sqrt{n} \approx \sqrt{\lambda\tau}$. So taking boundaries $\pm 3\sigma$, we will obtain:

$$\lambda_{\min} = \lambda_0 \cdot \left(1 - \frac{3}{\sqrt{\lambda_0 \tau}}\right), \quad \lambda_{\max} = \lambda_0 \cdot \left(1 + \frac{3}{\sqrt{\lambda_0 \tau}}\right), \tag{24}$$

where

$$\lambda_0 = \frac{\bar{\lambda}_0}{c_f(\beta_0, \delta)}, \quad \bar{\lambda}_0 = \frac{n}{\tau}.$$

3. Application of the method and results

The estimation of the expected maximum peak ground accelerations essentially differs from those concerning maximum magnitudes. First of all, direct measurements of seismic accelerations are very rare and fragmental. That is why there is no catalogs containing values of maximal accelerations for most sites of interest, but there are a lot of so called ‘attenuation laws’, which represent some functions between logarithm of maximal accelerations $R = \log(A_{\max})$, magnitude M of the earthquake and distance r from the considered site to epicenter of the earthquake:

$$R = \log(A_{\max}) = \Psi(M, r). \tag{25}$$

Usually functions (25) are empirical regression laws, obtained by collecting data from a specified region and fitting to them some class of functions. In our calculations we use the following attenuation law for Greece (Theodulidis, 1991; Theodulidis and Papazachos, 1992) for maximum horizontal peak ground acceleration:

$$\ln(A_{\max}) = 4.37 + 1.02M - 1.65\ln(r + 15) + 0.31S, \tag{26}$$

where acceleration is measured in cm/sec^2, r is the epicentral distance (km), M is magnitude, and S is the site geology coefficient, which is $S = 1$ for hard rock, $S = 0$ for alluvium and $S = 0.5$ for intermediate soil conditions.

Thus, the sequence (1) is composed of values, computed in accordance with the formula (26). As regression formula (25) give their ‘own’ errors due to errors of statistical fitting, the ‘general’ error ϵ is composed of two part: ‘own’ error (due to statistic fluctuations of data) and error due to incomplete adequacy of chosen class of functions in (25). We suppose that this general error has a zero mean and is distributed uniformly. We must also keep in mind that a ‘real’ relation of the type (25) must not be stationary and be dependent not only on soil and rock conditions, but on precipitation intensity to the moment of earthquake also. We choose a value of δ for uncertainty of $\ln(A_{\max})$ equal to 0.5 in our calculations as an approximately doubled value of standard deviation of the regression formula (26), in order to take into account influence of these factors on uncertainty.

Then for satisfying the assumption of Poissonian character of the events flow (1) we must remove aftershocks from the processed seismic catalogs. We could not leave only ‘usual’ mainshock because an event-aftershock with less value of magnitude, which has an epicenter closer to the considered site, could generate a larger peak acceleration than ‘usual’ mainshock. That is why the aftershocks’ removing procedure (Gardner and Knopoff, 1974) was modified in the following way: all events were divided into mainshocks and aftershocks. Afterwards, among each mainshock–aftershocks sequence only one event was left – those which generates the largest value of peak using formula (25).

Figure 1 presents positions of six selected sites in Greece, which were chosen for estimating seismic hazard parameters. Different symbol is used for each site

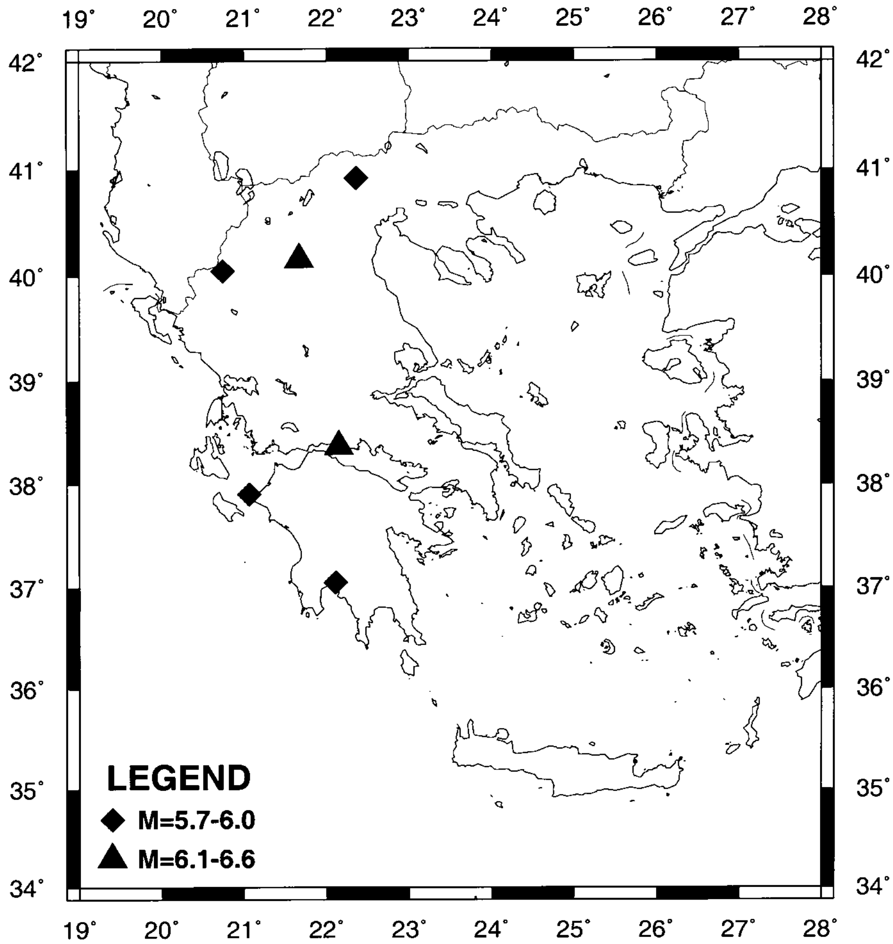

Figure 1. Map of Greece with positions of six sites, where seismic hazard has been estimated.

according to the occurred earthquake magnitude. Table I gives coordinates of the sites (latitude and longitude), the value of parameters S in attenuation law (26), minimum values R_0 of $\ln(A_{\max})$, numbers n of events, maximum past values R_τ (i.e., the maximum value of $\ln(A_{\max})$, which is given by the formula (26), at the given site, using the given catalog), values of the parameter $\rho_{\max}$ of the uncertainty domains Π, estimates (according to the formula (19)) of the slope β and maximum possible value ρ of $\ln(A_{\max})$ with their standard deviations.

Seismic hazard was estimated for time interval 1800–1999, after removing '$A_{\max}$-aftershocks', for epicenters' depth $\leq$ 100 km and values of $\ln(A_{\max}) \geq R_0$. The value of lower threshold R_0 was chosen from the following criteria:

(a) number of events n should be moderate (100–200);

(b) empirical function of tail distribution: $F_{\text{emp}}(X) = \text{Number}\{\ln(A_{\max}) > X\}/n$ must be close to the form of Gutenberg–Richter law.

Table I. Coordinates of sites, parameters of seismic acceleration data and results of estimates of ρ-maximum values of $\ln(A_{\max})$ and β-slope of recurrence law, with their standard deviations

Site	Lat.	Long.	S	R_0	n	R_τ	$\rho_{\max}$	$\hat{\beta} \pm$ stdv	$\hat{\rho} \pm$ stdv
Griva	40.95	22.38	1	2.0	144	5.60	7.0	1.67 ± 0.14	6.14 ± 0.49
Konitsa	40.05	20.74	1	2.5	157	6.04	7.5	1.64 ± 0.14	6.59 ± 0.52
Kozani	40.30	21.78	1	2.0	209	5.28	7.0	1.82 ± 0.13	5.92 ± 0.60
Aeghio	38.24	22.10	0.5	3.0	106	6.39	8.0	1.43 ± 0.15	7.07 ± 0.51
Killini	37.94	21.14	1	3.0	120	5.91	7.5	1.37 ± 0.15	6.30 ± 0.52
Kalamata	37.04	22.11	0	2.0	151	5.45	7.0	1.24 ± 0.12	5.86 ± 0.51

It should be underlined that the values of R_τ are not the results of instrumental observations or any other direct measurements but the results of using regression formula (26) to the catalog used and to the given sites. The method used does not need direct measurements of accelerations, it needs attenuation law and seismic catalog only.

It should be noticed a big value of $\hat{\rho}$ for Aeghio, which reaches the values of $1.2g$ ($g = 981$ cm/sec^2). This value turns to be maximum among all others, because maximum past value for Aeghio $R_\tau = 6.39$ (maximum among all other past values) and the slope of recurrence law is rather moderate (1.43).

Figure 2 presents graphs of empirical tail distributions for all sites for chosen values of R_0. Figures 3 and 4 give graphs of 0.5-quantile (median) and 0.9-quantile of distribution of apparent ρ-values in future time intervals of the lengths 5, 10, 20, 30 and 50 years with their standard deviations (formulae (20) and (21)). We choose quantiles for distribution of apparent value, because we do not deal with real peak accelerations, but with their estimates according to attenuation law (26). From this it follows that we should compute the ‘estimated’ values, which could be in future, if someone will try to use the law (26) for future data.

4. Discussion and Conclusions

Six earthquakes of moderate magnitude ($5.7 \le M \le 6.6$) occurred near six sites of Greece during period 1986–1999, where accelerographs were installed from the Institute of Engineering Seismology and Earthquake Engineering (ITSAK). These earthquakes occurred close to urban areas (villages and cities), so heavy damage and in some cases injuries and deaths were caused. According to the columns of Table II the reader can see tabulated, the site (city or village) which suffered from the earthquake, the year of occurrence and the magnitude of the mainshock, the epicentral distance, the observed values of acceleration in g, and the estimated acceleration (in g), through Bayes statistics. We want to notice here that the earth-

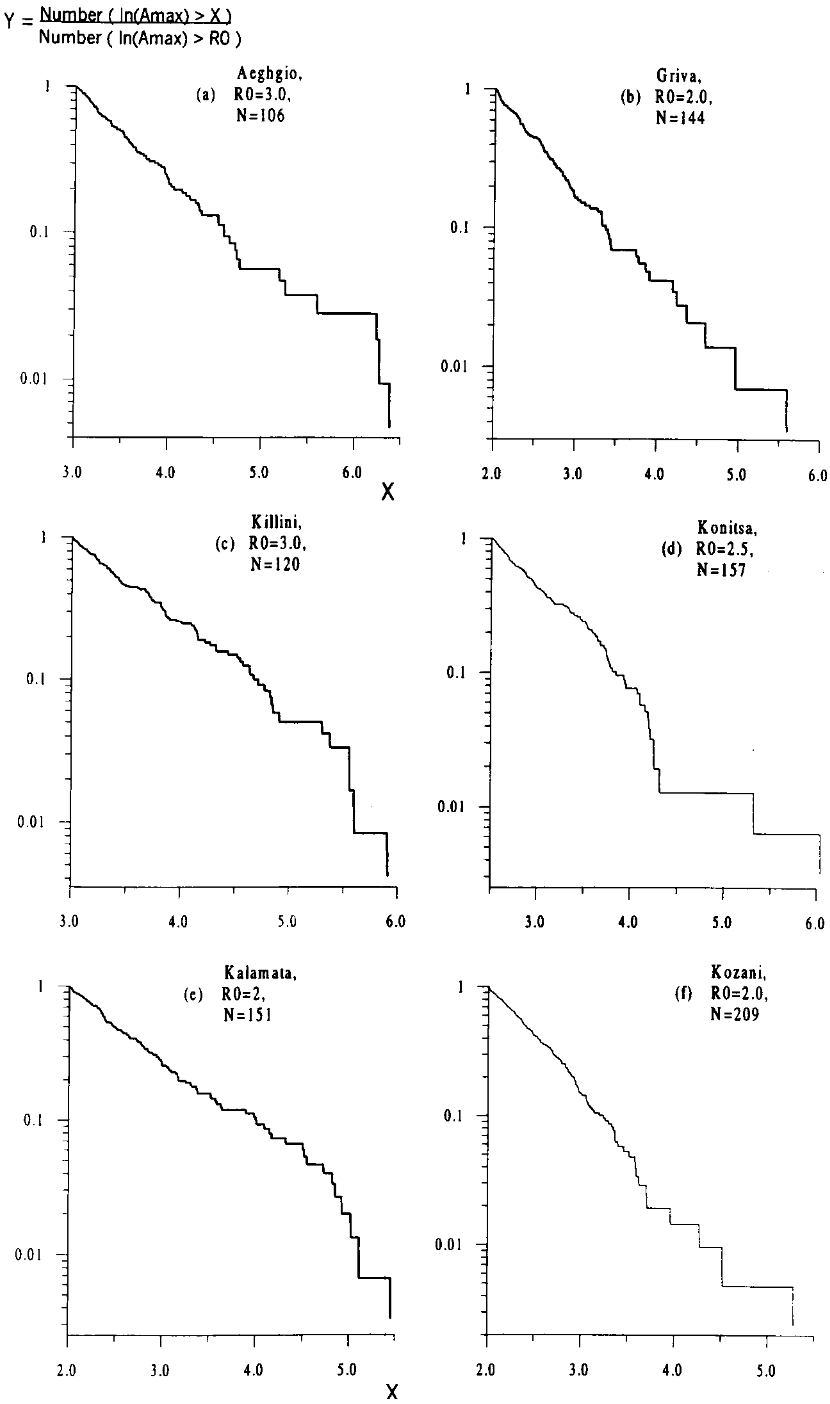

Figure 2. Empirical tail function of distribution of $\ln(A_{\max})$-values, computed for $\ln(A_{\max})$-main shocks for six different sites in Greece, 1800–1999, epicenters depth $\leq$ 100 km.

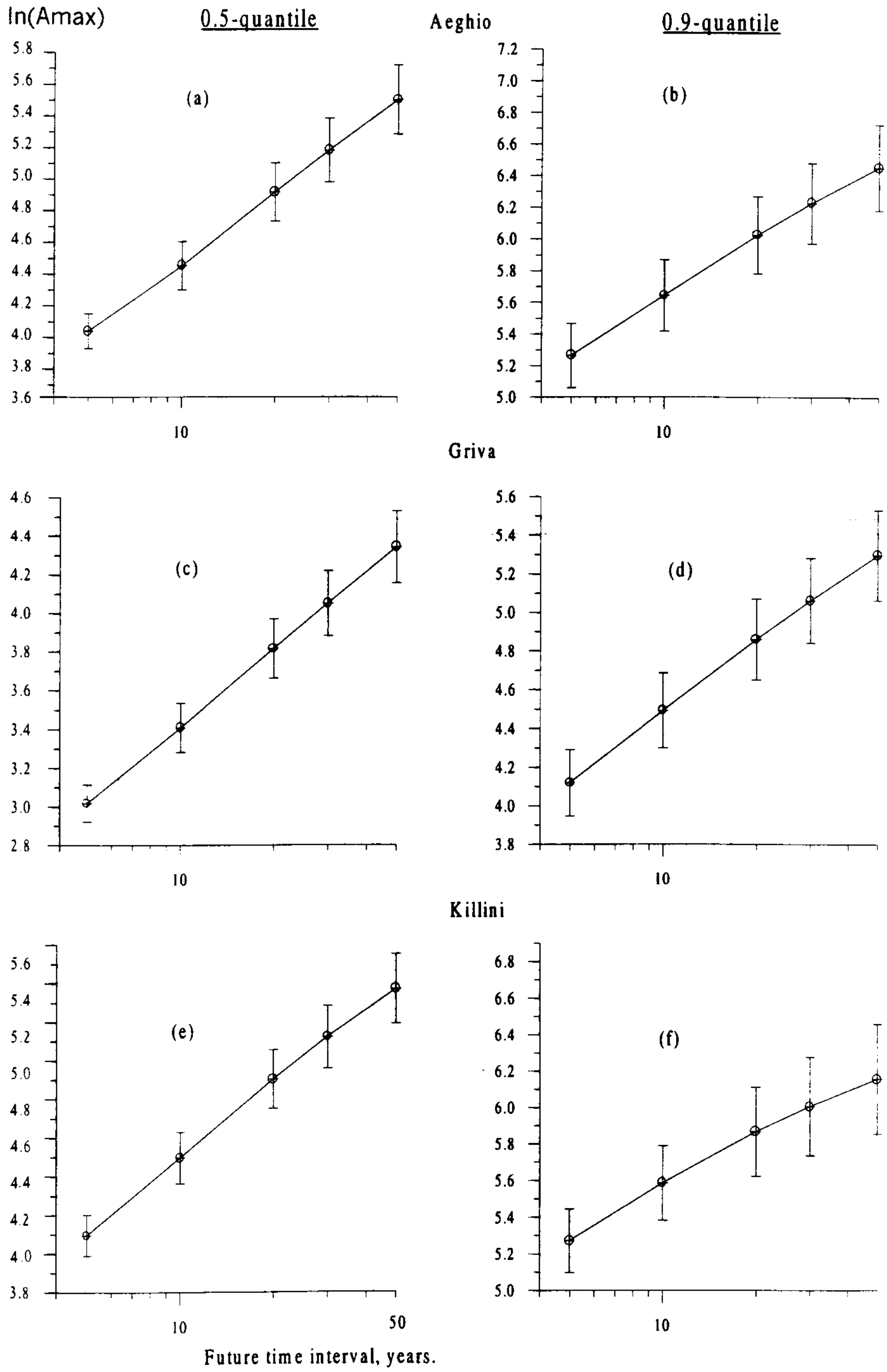

Figure 3. Estimates of 0.5- and 0.9-quantile of function of distribution of maximum values of $\ln(A_{max})$ for a number of future time intervals for 3 sites: Aeghio, Griva and Killini.

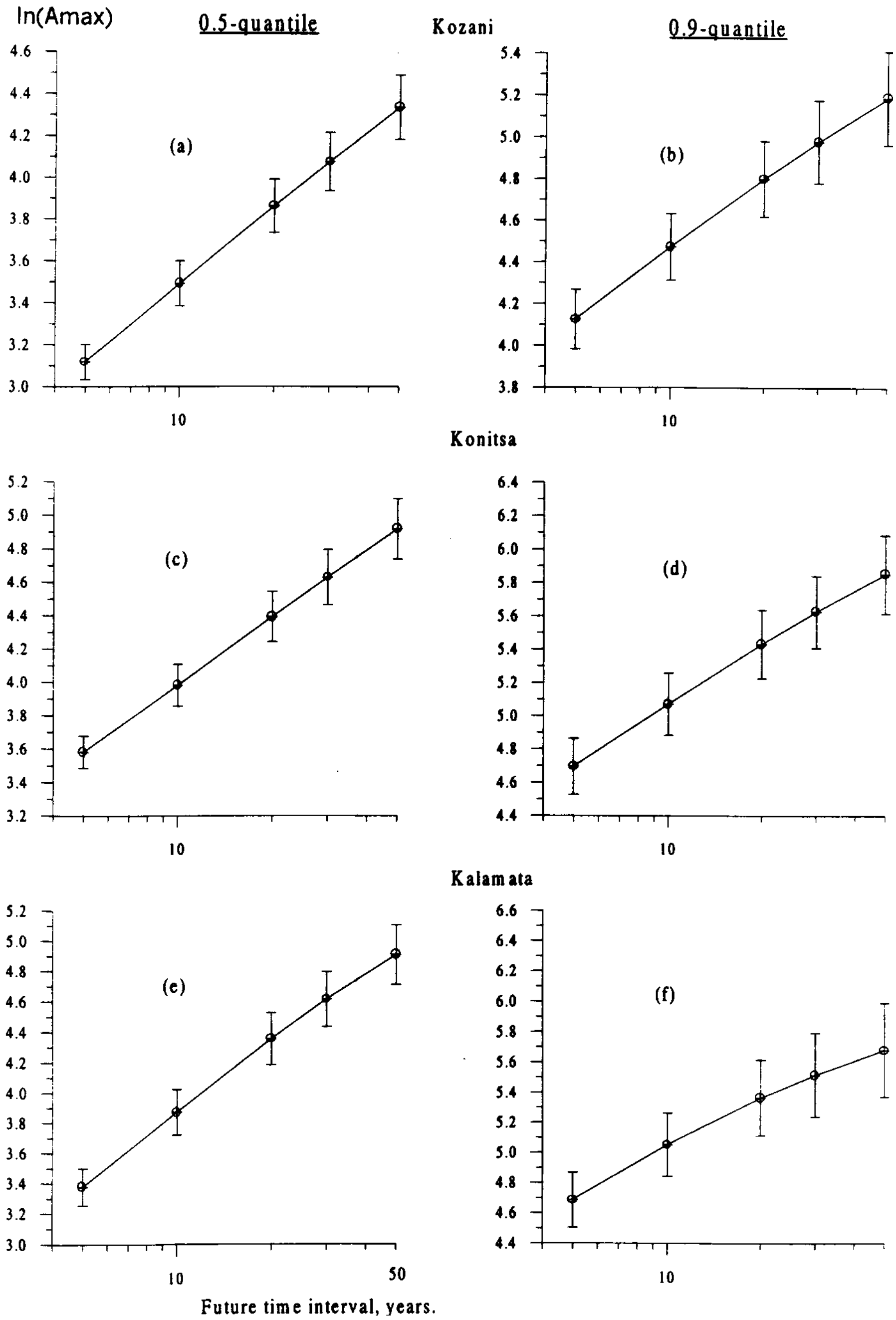

Figure 4. Estimates of 0.5- and 0.9-quantile of function of distribution of maximum values of $\ln(A_{max})$ for a number of future time intervals for 3 sites: Kozani, Konitsa and Kalamata.

Table II. The comparison between the observed and the maximum estimated acceleration obtained through Bayes procedure, in g. The sites are ranked according to the year of the occurrence of the earthquake. The number in brackets are the references of these specific earthquakes

City	Year	Magn.	Epicentral distance	Acceleration (in g)	
				Observed	Max. estimated
Kalamata (1)	1986	6.0	12 km	0.27	0.36
Killini (2)	1988	6.0	16 km	0.17	0.55
Griva (3)	1990	6.0	31 km	0.10	0.47
Kozani (4)	1995	6.6	19 km	0.21	0.38
Aeghio (5)	1995	6.4	18 km	0.54	1.19
Konitsa (6)	1996	5.7	10 km	0.39	0.74

(1): Anagnostopoulos *et al.*, 1987; (2): Theodulidis *et al.*, 1992; (3): Pitilakis *et al.*, 1992; (4) Theodulidis and Lekidis, 1996; (5): Lekidis *et al.*, 1999; (6): Theodulidis *et al.*, 1996.

quakes of Griva and Killini are recorded in the accelerographs installed in the cities of Edessa and Zakinthos, respectively.

A first inspection in Table II shows that the largest acceleration observed ($0.54g$) in Aeghio, where the maximum estimated acceleration is about $1.2g$. The lowest acceleration is observed ($0.10g$) in Griva. The maximum estimated acceleration for Griva could be $0.47g$ through the Bayes statistics evaluation. In Figure 5 we plotted the maximum estimated acceleration versus the observed acceleration for the six sites. The correlation is not perfect, with a correlation coefficient $R = 0.74$, but is not too bad to be rejected. So we can conclude that there is a correlation between these accelerations. There is a close correlation in Kalamata, given that the difference between the accelerations is only $0.09g$. In Aeghio about the half of the maximum estimated acceleration is generated during the occurrence of the earthquake of 1995.

The method of estimation of $A_{\max}(T)$ applied here is based on the straightforward Bayesian approach. Six sites in Greece, recently suffered catastrophic earthquakes are chosen for this purpose. The procedure adopted allows the statistical estimation of the peak ground acceleration that will occur in a given site and in a future time T. The results we obtained are derived by the application of the Greek attenuation law, which has the advantage that it includes the local geological conditions and a coefficient which describes the soil conditions. The adopted method allows us to control the efficiency of our estimations to quantiles of $A_{\max}(T)$, because according to our knowledge the quantiles are more adequate parameters to describe the seismic hazard than the distribution functions which are much popular and used by other scientists.

The Bayes approach, as was indicated by the method used, can be applied to any hazard analysis. The method is informative for the hazard studies and useful

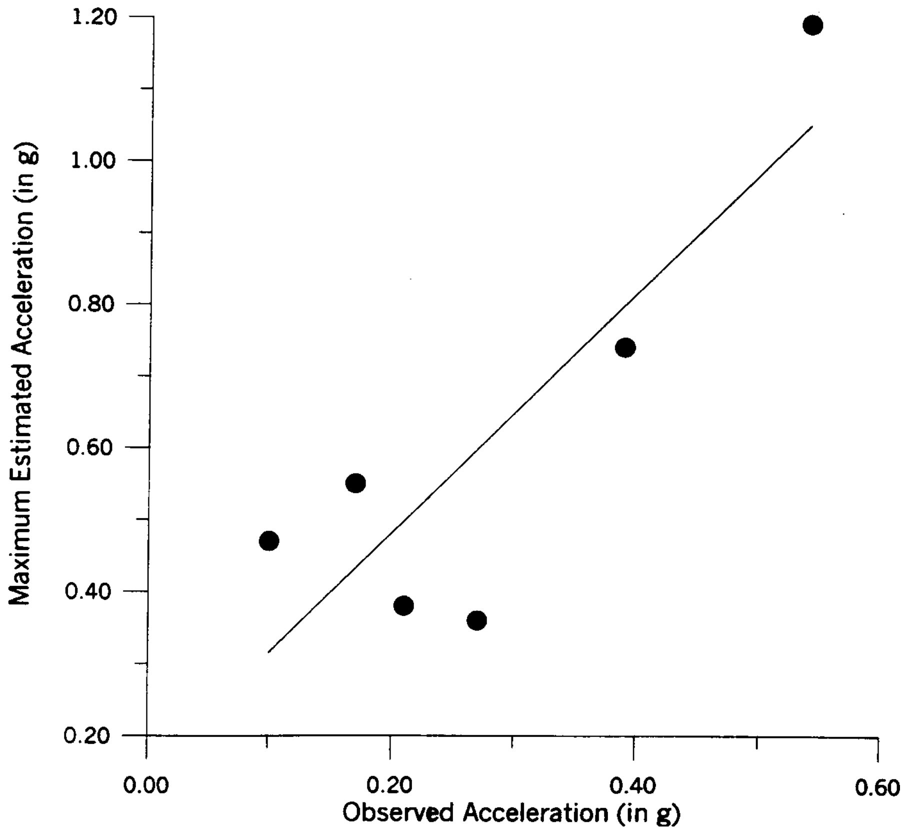

Figure 5. The correlation between the maximum estimated through Bayes approach and the observed acceleration.

not only from theoretical but also from practical point of view. Engineers can use the results for earthquake resistant designs.

Finally, the approach used should be compared with the method, recently elaborated for seismic hazard assessment in Greece in the paper (Papaioannou and Papazachos, 2000). This method is based on detailed regionalization of the territory of Greece and applying attenuation laws for macroseismic intensity. For consideration of the time-dependent hazard the main tool is the regression law between macroseismic intensity and the mean return period for large intensity values. The last step seems to be an indirect using of the primary seismological information, because the definition of return period includes estimating of function of distribution of intensity. The necessity of fitting some law for connection between return period and intensity is one more intermediate step in the method. Each intermediate step brings some uncertainty to the final result. From this point of view the method applied in this paper seems to be much more straightforward. It does not need any intermediate steps between the 'source' – (catalog plus attenuation law) and the 'target' – the estimates of maximum peak ground acceleration and its quantiles. Of course, the quality of the method should be estimated by its practical usefulness and there is a lot of work to test and compare different approaches for seismic hazard assessment.

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